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Transportable Continuous Emission Monitoring System Operational Protocol Instrumental Monitoring of SO2, NOx, CO2, and 02 Effluent Concentrations

(U.S.) Entropy Environmentalists, Inc.
Research Triangle Park, NC

Prepared for

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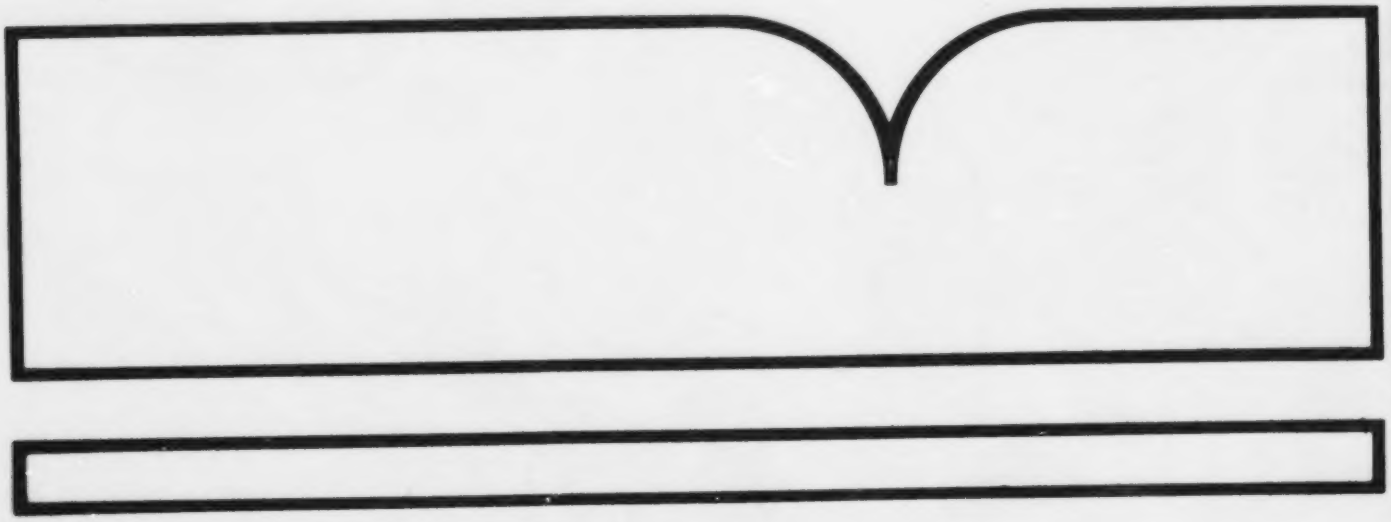

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ABSTRACT

A transportable continuous emission monitoring system (TCEMS) capable of providing reliable and accurate effluent measurements of SO_2, NO/NO_x, CO_2, and/or O_2 has been developed and field tested at numerous industrial and utility boilers. This report presents the operational protocol for the TCEMS, including set-up, operation, calibration, quality assurance, and data reduction procedures. The TCEMS and the operational protocol are designed for use in conducting source emission tests, continuous emission monitor (CEM) relative accuracy tests, and stratification tests. Extensive field testing has shown that the TCEMS can be set up, calibrated, and recording accurate and precise data within two to four hours after arrival at the site.

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Appendix II. Stratification Testing Methodology for Gaseous Effluent Constituents

INTRODUCTION

The use of portable and transportable continuous emission monitoring systems (TCEMSs) by industry, consultants, and control agencies for the measurement of gaseous effluent constituents at stationary sources has increased significantly in recent years. Control agencies can use TCEMSs cost effectively to conduct a variety of inspection/audit activities, such as: (1) measurement of SO_2 and/or NO_x emissions, (2) determination of the accuracy of installed continuous emission monitor (CEM) data, and (3) evaluation of the representativeness of proposed or existing CEM sampling locations. Source owners and operators can use TCEMSs to ensure compliance with applicable regulations and to ensure maximum process and control system performance.

The TCEMS offers several advantages over conventional Reference Method methodology for SO_2 and NO_x measurements. Both field set-up time and manpower requirements are significantly reduced when a TCEMS is employed. In addition, all or any combination of effluent constituents (SO_2, NO/NO_x, CO_2, and O_2) can be measured concurrently and with no increase in manpower requirements. TCEMs provide "real time" data, which allows corrective actions or additional tests to be initiated immediately, avoiding the usual delays caused by the time-consuming laboratory analyses and calculations required by the Reference Methods. The immediate availability of the data can also shorten the time required for relative accuracy tests. Finally, the TCEMS offers great versatility, allowing auxiliary tests (such as checks of monitor installation locations for stratification or checks of a source's calibration gas standards) to be conducted easily.

This report presents a TCEMS operational protocol that has been successfully field tested. The protocol specifies explicit, detailed procedures for operating the TCEMS during field tests to ensure consistent and valid results and to minimize the influence of operator expertise on the test results.

SECTION I.

TRANSPORTABLE CONTINUOUS EMISSION MONITORING SYSTEM: PRINCIPLE AND APPLICABILITY

A. Principle

An effluent gas sample is continuously extracted from a stack or duct through one or more single-point sampling probes. The sample is conditioned (i.e., water vapor and particulate matter are removed), and the sample is then transported to a series of gas analyzers for the determination of SO_2, NO_x, CO_2, and O_2.

B. Applicability

The transportable continuous emission monitoring system (TCEMS) is used for the determination of SO_2, NO, NO_x, CO_2, and O_2 concentrations at fossil-fuel-fired combustion processes. Before this methodology can be applied to other source categories and source-specific conditions, the validity of the TCEMS results must be established through sufficient comparative reference method test results.

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SECTION II.

APPARATUS

A. Pollutant/Diluent Analyzer

Table 1 lists the pollutant or diluent component, manufacturer, model number, and analytical technique for each analyzer in the prototype TCEMS. (The principles of operation for each analyzer are discussed in Appendix I of this report.)

Table 1.

Pollutant/ Diluent	Manufacturer	Model No.	Analytical Technique
SO_2	Beckman	865	IR Differential Absorption Spectrometer
NO, NO_x	Beckman	951	Chemiluminescence
CO_2	Beckman	864	IR Differential Absorption Spectrometer
O_2	Teledyne	320P-4	Electrocatalytic Fuel Cell

The SO_2, CO_2, and NO/NO_x analyzers are mounted in environmental isolated instrument cabinets for protection from adverse weather, temperature variations, and mechanical vibrations. Each analyzer is wrapped in two inches of polyurethane foam within the instrument cabinet. The instrument cabinet is also equipped with receptacles for electrical power, recorder wiring, and connectors for sample lines. (See Figures 1 and 2.)

B. Sample Handling System

The sample handling system provides a continuously conditioned (water vapor and particulate removed) sample gas flow for each of the gas analyzers.

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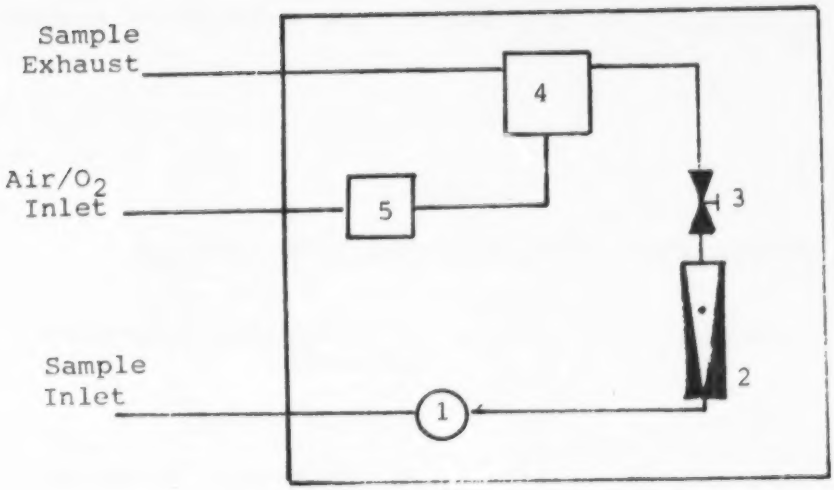
Figure 1.

NO_x Cabinet Plumbing Diagram



*1. Sample pressure regulator

*2. Sample rotameter

*3. Sample flow control valve

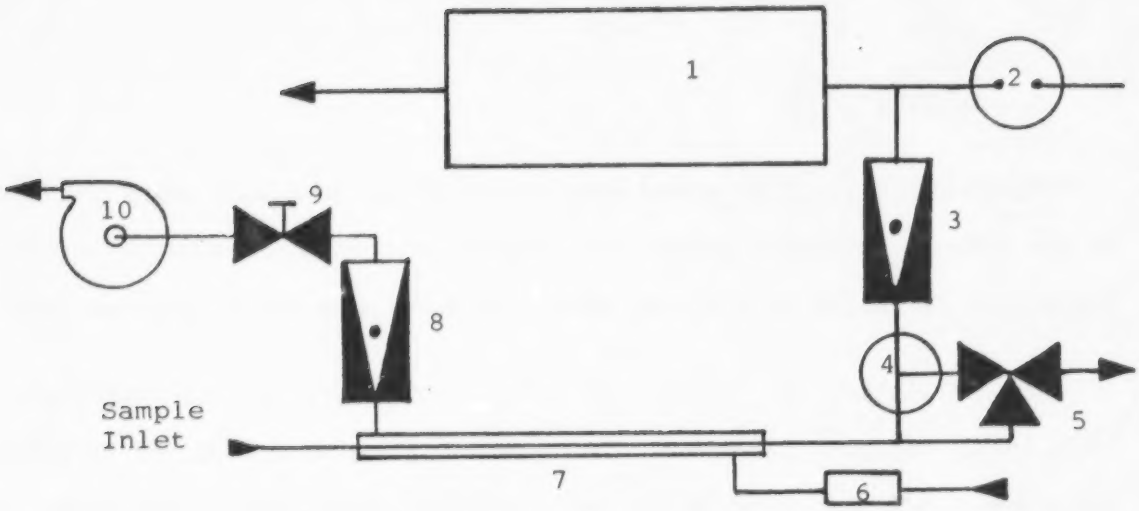
*4. Reaction chamber

*5. Ozone generator

*Built into the monitor

Figure 2.

CO_2/SO_2 Cabinet Plumbing Diagram



1. SO_2 or CO_2 gas monitor
2. Pressure gauge (in. of H_2O)
3. Sample rotameter with flow control valve
4. Bypass pressure regulator
5. Three-way calibration valve
6. Desiccant
7. Perma Pure dryer
8. Purge rotameter
9. Flow control valve
10. Purge pump

Table 2 lists the major components.

Table 2.

1. In-stack probe
2. In-stack coarse filter
3. Heated sample line
4. Primary moisture removal system
5. Gas transport tubing
6. Secondary moisture removal system
7. Fine filter
8. Pump
9. Calibration systems

1. Sampling Probe

Single-point sampling probes constructed of 316 stainless steel are used in the TCEMS. The sample probes are wrapped with Nichrome wire; a variable transformer is used to control the electrical power supplied to heat the probe.

For stratification tests, two single-point probes are used in a functionally parallel, time sharing fashion; one probe serves as the reference measurement, and the other serves as a traverse measurement. Each probe is equipped with a shut-off valve to facilitate switching from one to the other.

2. Coarse In-Stack Filter

A glass wool plug is inserted into the enlarged tip of the sampling probe to serve as a coarse in-stack filter. Quartz or borosilicate glass wool must be used.

3. Sampling Lines

The outlet of the sampling probe(s) is connected to the primary moisture removal system by 25 feet of 3/8-inch O.D. Teflon tubing wrapped with heating wire and insulation. Power to the sample line heaters is controlled with a variable transformer.

4. Primary Moisture Removal System

Combustion effluent streams contain significant amounts of water vapor. Therefore, an ice bath condenser is used as the primary moisture removal system to allow a relatively dry sample stream to be transported through unheated gas lines to the analyzer location. The ice bath condenser is constructed from a 20-foot section of 3/8-inch Teflon tubing wrapped in a 6-inch diameter coil. The gas passes through this coil to a condensate trap and then exits through a second port. A third and fourth port are incorporated in the condensate trap to facilitate both the injection of calibration gases and the draining of accumulated condensate. This entire system is contained in an insulated ice bath.

5. Gas Transport Tubing

3/8-inch O.D. Teflon tubing is used to transport the sample from the primary moisture removal system to the analyzer location. The length of the gas transport line should be kept as short as practical, but may be as long as 300 feet.

6. Secondary Moisture Removal System

A 12-inch Perma Pure dryer is used as a secondary moisture removal system to ensure that the sample stream is completely dry. A Thomas diaphragm pump pulls ambient air through a cartridge containing approximately 350 grams of 8-mesh Drierite and then through the outer shell of the dryer. Purge air flow rate is controlled by a rotameter and an in-line needle valve.

7. Fine Particulate Filters

A stainless steel, in-line, 40-mm filter holder, and 8-micron glass filters are used before the permeation dryer to prevent plugging with particulate matter.

The NO-NO_x analyzer requires a fine filter of less than 2 microns. A 40-mm Teflon filter holder and 2-micron glass filter paper are installed on the analyzer inlet port.

8. Pump

The TCEMS may be operated using either a Metal Bellows (MB) Model 158 or Thomas Model 2107CA18 pump. All internal parts of the pump that contact the gas sample are constructed of 316 stainless steel or Teflon.

9. Calibration Gas Systems

The sample handling system is equipped with two calibration systems to facilitate calibration of the total system: one local system to inject gases directly into the analyzers and a second system to inject calibration gases

directly after the in-stack probe. Both calibration systems are constructed of stainless steel or Teflon components.

All regulators used to control delivery pressures of pollutant gas calibration mixtures are constructed of 316 stainless steel; regulators constructed of other materials may be used for O_2 and CO_2 mixtures and zero air or nitrogen.

C. Data Handling System - Recorders

Two dual pen Soltec Model S4202 recorders are used to document permanently the outputs of the four analyzers.

SECTION III.

INSTALLATION

The sampling and analysis sites may be separated by as much as 300 feet The sampling site is dictated by: (1) the applicable source performance test and/or monitor performance specification test regulatory provisions, (2) the purpose of the test being conducted, and (3) the availability of accessible sampling ports (See Section VI, Sampling Procedures). The sampling probe, sampling line, primary moisture removal system, and stack calibration system must be installed at the sampling site. All other components of the sample handling system may be installed with the analyzers and data recorders at the analysis site.

The analysis site should be as close as is practical to the sampling site to minimize the response time of the system. Also, because the instruments are sensitive, the analysis location should be free from vibration. In selecting the analysis site, the following should also be considered: (1) operator convenience, (2) communication needs, (3) protection from severe environmental conditions (weather, noise, dust, temperature, noxious gases, etc.), and (4) available utilities.

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A. Utility Requirements

The analysis site power requirements are: 115 ± 15 VAC rms at 60 ± 0.5 Hz. Sufficient power must be available to operate the sample and purge pumps, analyzers, and data recorders. The supply voltage should be constant, without sharp fluctuations. After initial start-up, the power should be rechecked with all of the equipment operating to assure that proper voltage requirements are met.

The sampling site power requirements are nominal 115 VAC to provide power for operation of probe and sampling line heaters.

B. Sample Handling System Installation

The sample handling system is constructed of the sub-assemblies described in Table 3.

Table 3.

Assembly	Components
Probe	Probe; heat traced line.
Primary Moisture Removal System	Ice bath condenser, probe shut-off valve, calibration shut-off valve, condenser drain valve.
Stack Calibration System	Toggle shut-off valves and inlet fittings for calibration gases.
Gas Transport Tubing	50 to 300 ft of 3/8-inch tubing.
Pump	MB 158 pump, or equivalent, and fittings.
Secondary Moisture Removal System	Two Perma Pure dryers, fine filter, purge pump, purge desiccant.

Flow Control System	Stack gas shut-off toggle valve, flow meter, ground level calibration system.
Analyzer Flow Control System	Analyzer flow meters, flow control valves, and bypass flow control valve.

Figure 3 illustrates the interconnection of these sub-assemblies. Figure 4 shows the complete assembly of the sample handling system on a component-by-component basis.

1. Sampling Site

The probe is connected to the primary moisture removal system inlet by 3/8-inch heat-traced sample line. The calibration gases are connected to the calibration system by 1/4-inch Teflon lines; each gas is connected to its respective inlet. The output line of this system is connected to the calibration input fitting on the moisture removal system. A 50- to 300-foot, 3/8-inch Teflon gas transport line is connected to the outlet of the moisture removal system and run to ground level.

2. Ground Level

The 50- to 300-foot gas transport line is connected to the gas inlet port of the pump. Ground level calibration gases are connected to their respective ports by 1/4-inch Teflon tubing. The outlet of the pump attaches to the inlet of the secondary moisture removal system. The outlets of the Perma Pure dryers are connected to the inlets of the individual analyzer flow systems. In addition, the purge pump and purge desiccant are attached to the inlet and outlets, respectively, of the Perma Pure dryer shell.

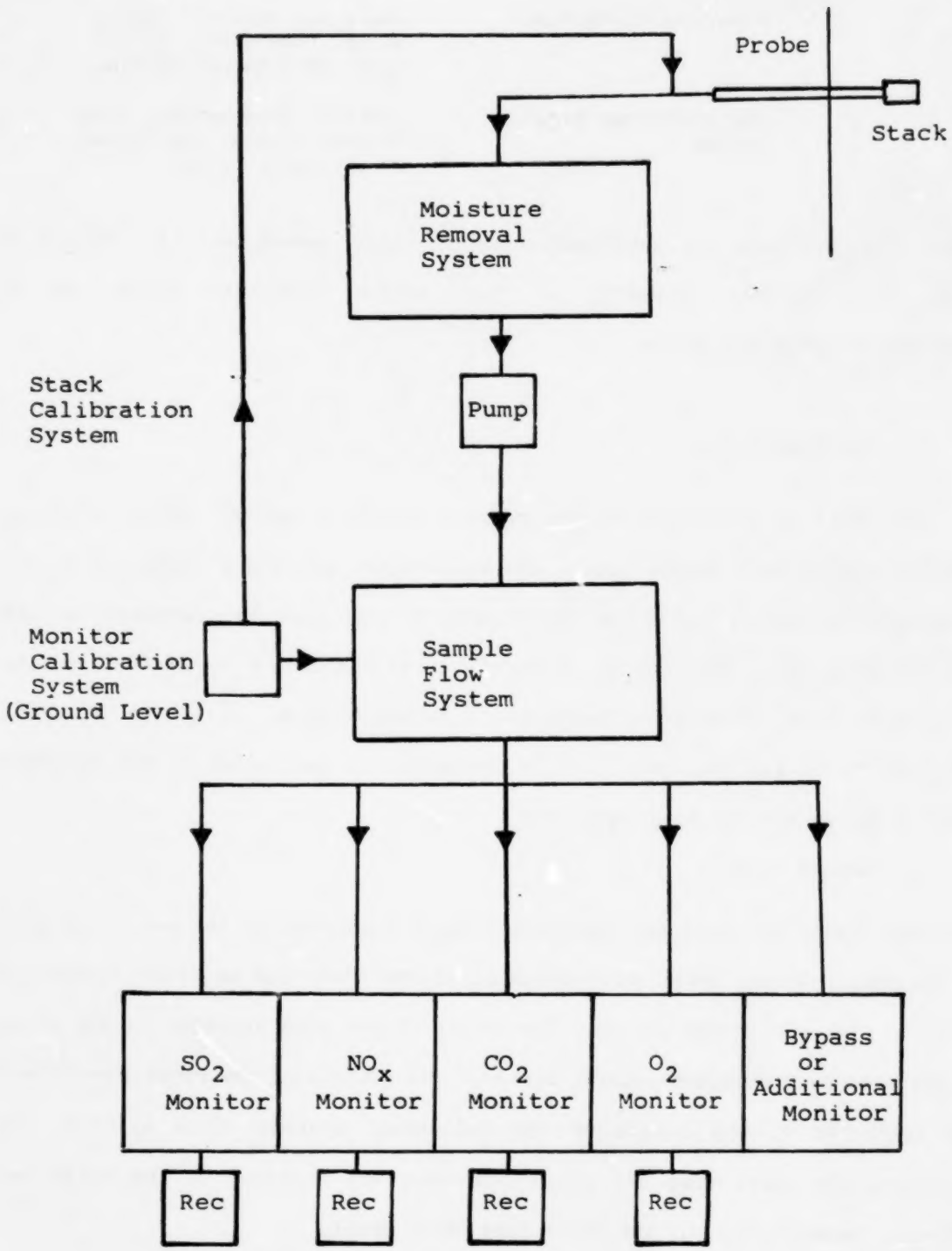

Figure 3. Continuous Gas Emission Monitor Block Diagram

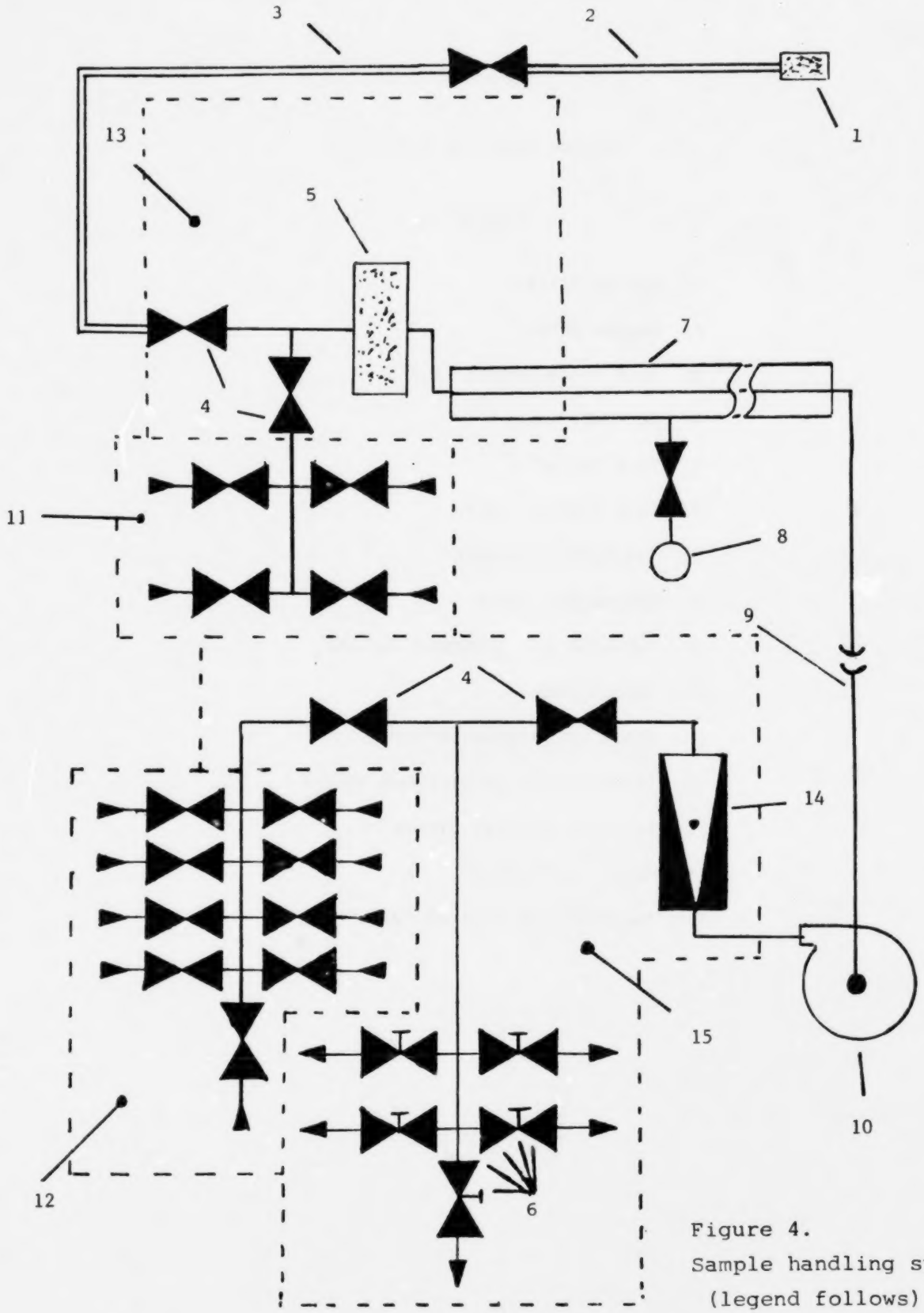

Figure 4.
Sample handling syste
(legend follows)

Figure 4.

Sample Handling System

Legend

1. Coarse filter
2. Heated probe
3. Heat trace sample line
4. Shut-off valve
5. Fine filter
6. Flow control valve
7. Ice bath condenser
8. Condensate drain
9. 3/8-inch gas transport tubing
10. Sample Pump
11. Stack calibration system
12. Ground level calibration system
13. Moisture removal system
14. Sample rotameter
15. Monitor flow control system

C. Analyzer Installation

All analyzer sample inlets should be connected to the appropriate lines from the analyzer flow manifold included within the sample handling system. All analyzer outlets and the sample by-pass flow should be properly vented to prevent a buildup of noxious gases at the analysis site. The vent lines should be large enough so that they do not cause a back pressure on any of the instruments.

The NO/NO_x analyzer requires compressed dry air for the operation of its ozone generator. The output of the zero air cylinder regulator is attached to the air inlet on the back of the monitor.

D. Data Recorder Installation

The strip chart recorders should be mounted adjacent to the analyzers in order to facilitate comparisons of meter readings and strip chart recorder values.

The SO_2 and CO_2 analyzers have three output wires: one red, one black, and one white. The white wire is not used. The red wire should be connected to the positive terminal, and the black wire to the negative terminal. No ground wire is necessary.

The NO/NO_x and O_2 analyzers have a two-wire output, with the positive going to the red terminal of the recorder and the negative to the black terminal.

Those monitors with environmental cabinets are equipped with red and black terminals with color-coded banana plugs, which simply plug into the recorders.

SECTION IV.

START-UP PROCEDURES

A. Leak Check Procedures

After the entire system has been assembled, a preliminary leak check is conducted. To perform a leak check, first shut off the toggle valve immediately after the probe. Next, shut off the monitor flow control valves. Cap the purge fittings of the Perma Pure dryer. Open the calibration system toggle valve at stack or ground level. Open the nitrogen cylinder valve, and adjust the regulator for approximately 20 psig. Wait momentarily for the whole system to be pressurized. Shut off the cylinder valve, and watch for any decrease in pressure on the cylinder pressure gauge for at least one minute. If a decrease in pressure is observed, the leak must be located and repaired. If no decrease in pressure occurs, the system is leak-free and the probe toggle valve can be opened to release the pressure.

B. Analyzer/Recorder Start-Up

1. SO_2 Analyzer

Turn the analyzer on, and allow a minimum of one hour for warm-up time.

2. NO/NO_x Analyzer

Turn on the dry air cylinder, and adjust the pressure regulator output to 40 psig. Open the front of the analyzer, and adjust the ozone pressure regulator to 20 psig. Turn on the power to the analyzer, and allow one hour for the instrument to warm up.

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3. CO_2 Analyzer

Apply power to the analyzer, and allow a minimum of one hour warm-up time.

4. O_2 Analyzer

No start-up procedures are required for the O_2 analyzer, since it is battery powered and completely self-contained.

5. Data Recorders

Two power switches are located on the front of the recorders, one for recorder power and one for chart drive. Turn on the main power, and allow the amplifier to warm up.

C. Sample Handling System Start-Up

1. Sampling Probe

Plug the probe heaters into the appropriate variable transformers, and adjust to the proper voltages (80 to 90%).

2. Sampling Line

Plug in the sample line heaters to the appropriate variable transformers. Adjust the voltages to approximately 80 to 90% of scale.

3. Ice Bath Condenser

Fill the condenser insulated container with ice.

4. Perma Pure Dryer

The Perma Pure dryer requires a dry air purge for the removal of water. The pump draws ambient air through a desiccant and through the dryer. Turn on the pump, adjust the flow rate to 8 L/min., and allow 30 minutes for equilibrium to be established.

5. Pump

After the rest of the system has come to equilibrium, open the probe valve and the sample by-pass valve. Turn on the pump, and stack gas will begin to flow through the system. After the system has been purged with effluent, adjust all of the monitor flow control valves to the proper flow rates for each of the instruments: SO_2 = 1 L/min, CO_2 = 1 L/min, NO_x = 4 L/min, and O_2 = 0.5 L/min.

SECTION V.

CALIBRATION

Proper calibration of the TCEMS requires sequential calibration procedures be conducted for : (1) all pollutant and diluent analyzers in use, (2) data recorders for each analyzer in use, and (3) total system calibration for each monitoring channel in use. To ensure the validity of all measurements obtained, the operator must follow all prescribed calibration procedures, and the TCEMS must demonstrate conformance with all prescribed acceptable calibration criteria.

A. Analyzer Calibrations

1. SO_2 Analyzer

Shut off the pump, and close the probe valve. Shut off the flow system toggle valve. Open the ground level calibration toggle valve. Open the cylinder cut-off valves, and adjust the regulators to provide delivery pressure of 5 psig. Open the N_2 toggle valve and adjust the SO_2 flow meter to 1 L/min. Check the built-in pressure gauge to make sure the cell pressure is below 4-in. H_2O. If it is not, adjust the sample bypass regulator to obtain 4-in. H_2O. Turn the range switch to "Tune" and look for a reading of 30 to 40 percent. If this reading is not obtained, refer to Section 7.3 of the Beckman 865 NDIR SO_2 Analyzer manual. Turn on the recorder for the instrument. Switch from "Tune" to Range 1. The reading should be zero; if not, adjust the zero control to zero. Switch between Ranges 1 and 3, to see if both read zero. If zero is not obtained on both ranges, refer to Section 7.5 of the instrument manual for bias adjustment procedures. If zero is the same for both Range 1 and Range 3, return to Range 1 and turn off N_2.

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Inject a high range span gas, and set the gain control for the appropriate reading. If the reading cannot be obtained, or if a negative deflection is observed, refer to Section 7.6 of the instrument manual. Once the proper deflection is obtained, shut off the high range gas, and inject a second gas in the mid-range. If the proper reading is not obtained, the linearizer circuit is out of calibration. The linearizer circuit calibration procedure is contained in the appendix of the instrument manual. Once the proper output has been obtained, the instrument is ready for use. Shut off the span gases and the flow control valve, and proceed to the next analyzer.

2. NO/NO_x Analyzer

Set the monitor to the NO_x mode, and select the range to be used (e.g., 1000 ppm range). Inject the N_2 gas. Open the flow control valve so that a reading of 5 cfh is obtained. Open the front cover and adjust the sample pressure regulator for 4 psi. Also adjust the sample bypass flow meter to 20 (i.e., 2000 cc/min). If zero is not obtained, adjust the zero control for zero meter output. If zero cannot be obtained, refer to Section 6 of the Beckman 951 Chemiluminescence Analyzer instrument manual.

Once zero has been obtained, inject a high concentration span gas by opening the appropriate toggle valve. Open the front of the instrument and check the sample pressure (4 psi) and the sample byass flow (20). Close the front, and watch for the proper deflection of the meter or recorder. If necessary, adjust the span control for the proper reading. If the proper reading cannot be obtained, refer to Section 6 of the instrument manual. Once the proper reading is shown, shut off the high span gas, and inject an intermediate gas to check for linearity. Make sure that the sample pressure and the sample bypass flow are set correctly. If the reading is incorrect, refer

to Section 6 of the instrument manual. If the correct readings are obtained, shut off the span gases, and proceed to the next analyzer.

3. CO_2 Analyzer

Shut off the pump, and close off the probe valve. Shut off the flow system toggle valve. Open the ground level calibration toggle valve. Open the cylinder cut-off valves so that N_2 and CO_2 gases may be injected. Adjust the regulators for 5 psig. Open the N_2 toggle valve, and adjust the CO_2 flow meter to 1 L/min. Check the built-in cell pressure gauge. If the reading is not below 4-in. H_2O, adjust the bypass regulator for minimum cell pressure while maintaining a 1 L/min sample flow.

While continuing to inject N_2, turn the range switch to "Tune" and check for a reading of 30 to 40 percent. If this reading is not obtained, refer to Section 7.3 of the Beckman 864 CO_2 Analyzer instrument manual. Turn on the recorder for the instrument. Switch from "Tune" to Range 1. The reading should be zero; if not, adjust the zero control to zero. Switch between Range 1 and Range 3 to see if both read zero. If zero is not obtained on both ranges, refer to section 7.5 for bias adjustment. If zero is the same for both Range 1 and Range 3, return to Range 1 and turn off the N_2 toggle valve.

Inject a high range span gas and set the gain control for the appropriate reading. If the reading cannot be obtained, or if a negative deflection is observed, refer to Section 7.6 of the instrument manual. Once the proper deflection has been obtained, shut off the high range gas, and inject a second gas in the mid range. If the proper reading is not obtained, the linearizer circuit is out of calibration. The linearizer circuit calibration procedure is contained in the appendix to the instrument manual.

Once the proper output has been obtained, the instrument is ready for use. Shut off the span gases and the flow control valve, and proceed to the next analyzer.

4. O_2 Analyzer

Remove the flow-through adaptor, and place the range switch in the "high" position. Press the pump switch, and sample ambient air. Rotate the span control until the meter pointer is positioned on the red mark. Attach the inlet of the analyzer to the O_2 flow meter outlet. Inject N_2 to verify instrument zero. Flow several concentrations of O_2 to check the linearity of the instrument. If these checks give improper readings, refer to the Teledyne 320P-4 Micro-Fuel Cell O_2 Analyzer instruction manual.

B. Data Recorder Calibrations

1. SO_2 Channel

The SO_2 analyzer is equipped with a 4- to 20-ma output. The recorders will accept a voltage input only. Thus, the recorders are equipped with a 50-ohm resistor to convert the current output to a voltage. Since 4 ma is equivalent to zero concentrations, and since a finite voltage is developed, a variable span recorder must be used. To achieve the correct recorder zero and span settings, pull the recorder zero control to its "out" position. Select the 1 volt range. With the instrument meter on zero, adjust the recorder zero control for 10 percent of the recorder scale. Inject a gas into the instrument to get an upscale deflection, and adjust the variable span potentiometer to obtain the same value as the meter reading. Return to zero, and adjust if necessary. Inject the gas again, and adjust the span variable again. Continue

this iterative procedure until the zero and span values are balanced.

2. NO/NO_x Channel

The output of the NO/NO_x analyzer is 0 to 1 volt DC. Zero the monitor and adjust the recorder zero for 10 percent of the scale. Inject a high range gas, and check that the recorder reads the same as the meter. If the readings are not the same, refer to the Soltec recorder manual for the span adjustment procedures, Section 3. Check the zero and upscale readings until the zero and span settings are balanced.

3. CO_2 Channel

The CO_2 analyzer is equipped with a 4- to 20-ma output. The recorders will accept a voltage input only. The recorders have been supplied with a 50-ohm resistor to convert the current output to a voltage. Since 4 ma is equivalent to zero concentrations, and since a finite voltage is developed, a variable span recorder must be used. The correct zero and span settings may be achieved by pulling the recorder zero control to its "out" position. Select the 1 volt range. With the instrument meter on zero, adjust the recorder zero control for 10 percent of the recorder scale. Inject a gas into the instrument for an upscale deflection, and adjust the variable span potentiometer to obtain the same value as the meter reading. Return to zero, and adjust if necessary. Inject the gas again, and adjust the span variable again. Continue this iterative procedure until the zero and span values are balanced.

4. O_2 Channel

The output of the analyzer is 0 to 100 mv DC. Inject a low concentration of O_2 into the monitor, and adjust the recorder for 10 percent of scale above the low concentration value. Inject a high range gas, and check that the recorder reads the same as the meter. If the readings are not the same, refer to the Soltec recorder manual for the span adjustment procedures, Section 3. Check the low and upscale readings until the low and span settings for the recorder are balanced.

C. Total System Calibration

After the individual analyzer and data recorder calibrations are completed, a total system calibration must be performed. All span gases used in this check should represent values close to those of the stack effluent. Shut off the probe valve and the pump. Open the stack calibration system toggle valve. Open the N_2 and the span gas cylinder valves, and adjust the output of the regulators to 10 psig. Open the N_2 toggle valve. Turn on the pump and adjust the instrument flow meters for the proper flows (SO_2 = 1 L/min; NO-NO_x = 4 L/min; CO_2 = 1 L/min; and O_2 = 0.5 L/min). All instrument outputs should equal zero. Open the system to ambient air to check whether air and N_2 give the same reading. If not, the Perma Pure dryer has not yet come to equilibrium, and a longer period of time is necessary for the dryer to purge.

[Note: Since the SO_2 analyzer is subject to H_2O interference, a zero offset may be detected on the SO_2 analyzer when the total system calibration is attempted. The zero offset will occur because of a reverse action in the Perma Pure drying process during calibration. When the purge gas is not completely dry, the water vapor permeates from the outer shell of the dryer to the inner shell. This permeation occurs because the calibration gases are dryer than the purge gases, and the diffusion potential is temporarily reversed.]

Inject SO_2 and record the responses of the SO_2 analyzer and data recorder. Shut off the SO_2, and inject NO_x, CO_2, and O_2 consecutively. Record the response of the analyzer and the recorder for each measurement. During these calibration gas injections, only the analyzer corresponding to the particular span gas injected should provide a non-zero output.

The response of each analyzer and each data recorder must be converted to units of concentration and compared to the assigned value of the calibration gas mixture used in the system calibration. The response must be within $\pm$ 3 percent of the calibration gas value for the performance of each monitoring channel to be considered acceptable. If such results cannot be obtained, necessary adjustments and/or repairs must be made, and the entire calibration procedure repeated.

SECTION VI.

SAMPLING PROCEDURES

Sampling can commence only after all calibration procedures have been successfully completed.

A. Final TCEMS Adjustments

To sample stack gases, close all calibration system toggle valves, and open the probe toggle valve. Open the bypass valve on the analyzer flow system, and turn on the pump. Adjust the SO_2 and CO_2 flow meters to 1 L/min. Adjust the NO-NO_x flow meter to 4 L/min. Open the front panel of the NO-NO_x analyzer, and adjust the sample pressure to 4 psi, and the bypass flow to 20 (i.e., 2000 cc). Adjust the O_2 flow meter to 0.5 L/min. If these flows cannot be established, close the bypass valve until all flows are balanced. All instruments should now correctly read the effluent concentration values.

B. Sampling Points

Selection of sampling points for the TCEMS depends upon the type of test being conducted (source performance test or monitor performance test), and upon the constraints imposed by applicable regulations and available sampling ports.

1. Emission Tests

All relevant regulatory provisions regarding the location of Reference Method sampling points during source performance tests apply to the TCEMS during tests to determine SO_2 and/or NO_x emission levels. Whereever such

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provisions do not specifically prescribe sampling points and where the sampling location may not provide representative results, a stratification test must be performed using the procedures detailed in Appendix II of this report.

2. CEM Performance Tests

All relevant regulatory provisions regarding the location of Reference Method sampling points during relative accuracy tests apply to the TCEMS during CEM performance tests.

If relative accuracy testing is conducted at a location other than the installed CEM location where the TCEMS location may not give representative results, a stratification test must be performed at the TCEMS location according to the procedures specified in Appendix II of this report. The relative accuracy test results that are obtained where the TCEMS location is separated from the installed CEMS location cannot distinguish between factors impacting the actual performance of the installed CEM and the potential effects of stratification at the installed CEM location.

If relative accuracy testing is conducted at the same location as the installed CEM location where the location may not provide representative results, a stratification test must be performed according to the procedures specified in Appendix II of this report. When relative accuracy testing is conducted at the same location as the installed CEM, the following sampling points must be used:

a. Single Point CEMS

For single point CEMS, the TCEMS sampling probe should be located no further than 30 cm (or 5 percent of the equivalent diameter of the cross section, whichever is less) from the pollutant CEM sampling probe.

b. Multipoint CEMS

For multipoint CEMS, each TCEMS sampling probe traverse point should be located no further than 30 cm (or 5 percent of the equivalent diameter of the cross section, whichever is less) from each corresponding pollutant CEM sampling point.

c. Path CEMS

For limited path and path CEMS, three TCEMS sampling points should be located on a line parallel to the CEM path and no further than 30 cm (or 5 percent of the equivalent diameter of the cross section, whichever is less) from the centerline of the CEM path. The three points for the TCEMS sampling probe should correspond to points in the CEM path at 16.7, 50.0, and 83.3 percent of the effective length of the CEM path.

d. Alternative Locations

Other locations may be used if a stratification check is conducted and the pollutant and diluent constituents of the gas stream are found to be of uniform concentration throughout the measurement area of interest within the stack. (See Appendix II.)

C. Sampling Duration/Calibration Frequency

Sampling durations for the TCEMS must be consistent with the applicable regulatory provisions for source performance tests and monitor relative accuracy tests.

1. SO_2 and NO_x Emission Tests at NSPS Subpart D Sources

After all calibration procedures have been successfully completed, the TCEMS must be operated for three one-hour sampling runs. A system calibration of the TCEMS (See Section V, C) must be successfully completed before and after each sampling run. If the system calibration is not successfully completed, adjustments and/or repairs to the TCEMS must be made and a complete recalibration of the TCEMS must be performed.

Data obtained during a sampling run followed by an unsuccessful system calibration may not be included in the calculation of emission levels.

2. Relative Accuracy Tests of Installed SO_2 and NO_x CEMS

After all calibration procedures have been successfully completed, the TCEMS must be operated for 9 sampling runs to provide results comparable to the relative accuracy test of Appendix B, Performance Specifications 2 and 3, 40 CFR 60. The TCEMS must be operated for 6 sampling runs to provide results comparable to the relative accuracy audit of proposed Appendix F. The duration of each sampling run shall be 20 minutes. A system calibration of the TCEMS must be successfully completed before and after each sampling run. If a system calibration is not successfully completed, adjustments and/or repairs to the TCEMS must be made and a complete calibration of the TCEMS must be performed. Data obtained during a sampling run that is followed by an unsuccessful system

calibration may not be included in the determination of the installed CEM relative accuracy.

In those cases when either gross disparities or excellent agreement between the installed CEMS and the TCEMS are observed during the initial sampling runs, it is usually possible to predict accurately the outcome of the relative accuracy determination before all the required sampling runs are completed. Table 4 lists the criteria for termination of relative accuracy sampling where conformance with the promulgated Performance Specifications is not required. Procedures for calculation of the mean difference are specified in Section VIII.

Table 4.

Sample Runs Completed	Percent Difference*	Results Installed CEM Performance
3	PD > 20%	unacceptable
3	PD < 10%	acceptable
6	PD > 20%	unacceptable
6	PD < 14%	acceptable

* PD = Percent Difference = $\left| \frac{\sum_{i}^{N} (CEMS_i - TCEMS_i)}{\sum_{i}^{N} TCEMS_i} \right|$

N = Number of sample runs

These criteria are based on limited available data at the time of preparation of this report; more restrictive criteria will be developed as additional data become available.

SECTION VII.

QUALITY ASSURANCE PROCEDURES

The most important quality assurance procedures for the TCEMS are those specified for the analyzer, data recorder, and system calibration in Section V. The calibration results provide the primary basis for assessing the quality of the measurement results obtained. Additional quality assessment and quality control procedures are specified below.

A. Analyzers

1. SO_2 Analyzer

The SO_2 analyzer is sensitive to flow rate and sample pressure variations. Therefore, the bypass valve should be open as far as possible, and the supply flow rate should be kept at 1 L/min.

> [Note: The monitor is equipped with a pressure gauge calibrated in inches H_2O. The pressure of the cell is pe-set by a bypass regulator. This sample pressure should be maintained at 4 $\pm$ 0.5 in. H_2O.] The operator should check the sample flow rate and sample pressure during each sampling run.

The SO_2 analyzer is equipped with an internal reflector to provide an upscale calibration check of the analyzer response. The set point of this refector should be noted during the analyzer calibration procedure. The internal reflector should be activated periodically during sampling to check for analyzer drift. Any discrepancy greater than 2 percent between the analyzer's response to the internal reflector and the results of system calibrations should be resolved, and the analyzer should be recalibrated.

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2. $NO-NO_x$ Analyzer

The $NO-NO_x$ analyzer is sensitive to sample pressure and sample flow rat fluctuations. A check of sample pressure (4 psig) and sample bypass flow (20, indicating a flow of 2000 cc/min.) should be conducted during each sampling run. A pressure of 20 psi on the ozone pressure gauge will assure that the ozone generator is receiving enough air flow. The inlet gas sample is passed through a glass fiber filter to remove particles larger than 2 microns. Before each field use, the glass filters should be visually checked and replaced if any discoloration is observed.

3. CO_2 Analyzer

The CO_2 analyzer is sensitive to sample flow rate and sample pressure fluctuations. Therefore, the bypass valve should be open as far as possible, and the flow should be kept at 1 L/min.

[Note: The monitor is equipped with a pressure gauge in inches H_2O. The cell pressure is pre-set, but should be checked. The pressure must be maintained within 4 $\pm$ 0.5 in. H_2O.]

The CO_2 analyzer is equipped with an internal reflector to provide an upscale calibration check of the analyzed response. The set point of this reflector should be noted during the analyzer calibration. The internal reflector should be periodically activated during sampling to check for analyzer drift. Any discrepancy greater than 2 percent between the analyzer's response to the internal reflector and the results of a system calibration should be resolved, and the analyzer should be recalibrated.

4. O_2 Analyzer

The O_2 analyzer has a self-contained battery pack, which should be charged after every field use. When the analyzer is not in use, the cell cap should be replaced to prolong the life of the cell. After use, the sample cell should be purged with air. Sampling time should be as short as possible (approximately 1 minute), in order to extend the life of the cell.

B. Sample Handling System

1. Probe

The probe should be cleaned before and after use. The glass wool plug must be replaced after each field test. Heater wires should be inspected to reduce the chance of heater outages during use.

2. Primary Moisture Removal System

The ice bath condenser should be drained and cleaned before and after use.

3. Fine Particulate Filter

This filter should be changed after each use.

4. Secondary Moisture Removal System

The purge air desiccant for the Perma Pure dryer should be replaced after each use and checked periodically during use. When the desiccant is close to being spent, it should be replaced immediately. If the desiccant is not replaced, the moisture in the ambient air will allow a portion of the sample

stream moisture to pass through the Perma Pure dryer. This small amount of moisture represents a negligible volume fraction of the sample, but can cause a zero offset on the SO_2 and CO_2 monitors.

The Perma Pure dryer used in the moisture removal system removes the effluent moisture in the vapor state. Entrained moisture droplets in the effluent will cause a saturation of the membranes in the Perma Pure dryer. This moisture will eventually contaminate the whole monitoring system, rendering the SO_2 and CO_2 monitors incapable of obtaining accurate effluent measurements. If moisture appears at any point in the system after the dryer, the total system must be shut down and the problem with moisture carryover resolved.

5. Gas Transport Tubing

The 50- to 300-foot gas transport lines should be kept as clean as possible. If necessary, these lines can be cleaned with soapy water and rinsed thoroughly with distilled water. Afterwards, the lines should be dried with a continuous flow of ambient air.

6. Pump

No routine maintenance of the sample pump is necessary.

7. Flow System

No maintenance is required.

8. Analyzer Flow System

This system should be maintenance-free. If the rotameters should stick, wash them with soapy water, and then rinse with distilled water. Do not tighten the flow valves too tightly; this may cause damage to the valve seats.

C. Data Handling System - Recorders

The recorders should be kept clean in order to reduce friction in the mechanical moving parts. Calibration should be performed before and after use to check for amplifier drift.

D. Calibration Gases

Concentration values of calibration gases used with TCEMS may be determined by either of the following methods:

1. Calibration gas values traceable to NBS standards may be established according to "Traceability Protocol for Establishing True Concentrations of Gases Used for Calibration and Audits of Continuous Source Emission Monitors (Protocol No. 1)." June 15, 1978.

2. Triplicate reference method analyses of each calibration gas may be performed. Each of the individual analytical results must be within 10 percent (or 15 ppm, whichever is greater) of the average; otherwise, discard the entire set, and repeat the triplicate analyses. If the average of the triplicate reference method test results is within 5 percent of the calibration gas manufacturer's tag value, use the tag value; otherwise, conduct at least 3 additional reference method test analyses until the results of 6 individual runs (i.e., the 3 original plus 3 additional) agree within 10 percent or 15

ppm, whichever is greater, of the average. Then use this average for the cylinder value.

SECTION VIII.

DATA INTERPRETATION

All data reduction procedures are based upon the fully documented strip chart records of the TCEMS. All zero, span, and effluent measurements must be clearly marked for each of the monitoring channels in use.

A. General Data Interpretation Procedures

The zero and span system calibration results for each monitoring channel are used to evaluate all effluent monitoring results. The following procedure must be used:

zero level = strip chart reading during zero gas (air) injection (in chart divisions)

span level = strip chart reading during upscale system calibration (in chart divisions)

span value = calibration gas concentration corresponding to upscale system calibration (in ppm or percent)

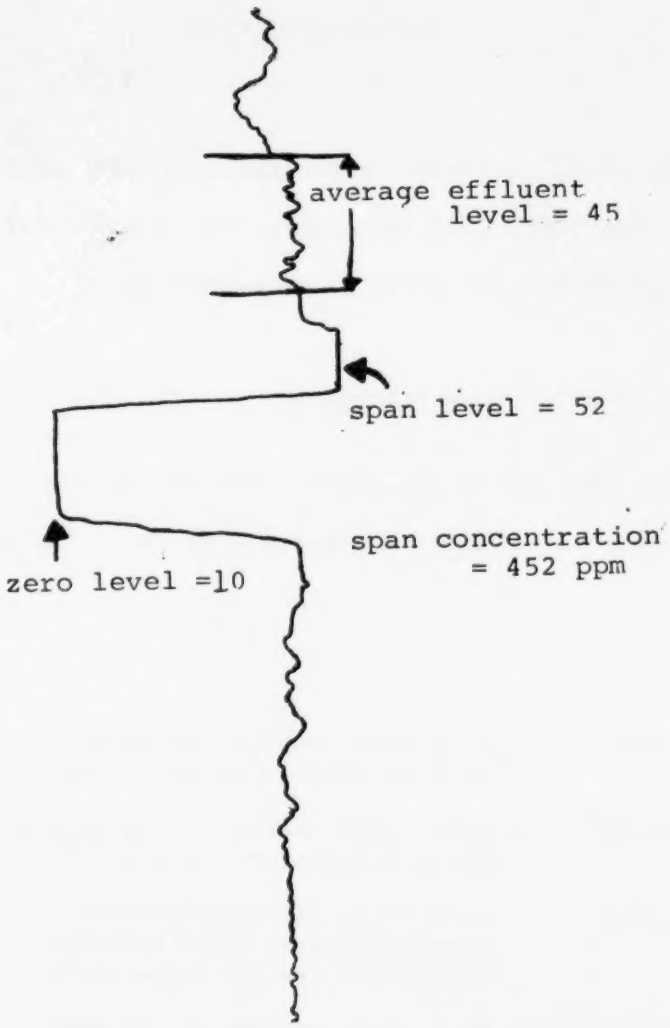
effluent level = strip chart reading of effluent measurement (in chart divisions)

effluent value = effluent concentration (in ppm or percent)

$$\text{scale factor} = \frac{\text{span value}}{\text{span level} - \text{zero level}} \quad \text{(in ppm per chart division)}$$

effluent value = [effluent level-zero level]x[scale factor]

The above procedure is illustrated in Figure 5.



$$\text{scale factor} = \frac{452}{52 - 10} = 10.762 \text{ ppm/chart division}$$

$$\text{effluent value} = [45-10] \times 10.762 = 377 \text{ ppm}$$

Figure 5. Interpretation of strip chart records

B. SO_2 and NO_x Source Performance Test Results

Interpretation of TCEMS data for determining source emission levels should be as consistent as possible with applicable reference method and regulatory considerations.

For SO_2 emission level determinations at NSPS Subpart D sources, the following data reduction procedures are applicable:

(1) Ignore the first 5 minutes of sampling data obtained during each one-hour sampling run to allow for complete system stabilization following the system calibration. Divide the remaining sampling time into two equal duration sampling periods per sampling run for both the SO_2 and diluent (CO_2 or O_2) monitoring channels.

(2) Determine the average effluent level for both the SO_2 and diluent monitoring channels for each sampling period. Convert the effluent levels to equivalent effluent concentrations for both monitoring channels using the procedure in "A" above.

(3) Using the SO_2 and diluent concentrations, calculate emission levels in units of $lbs/10^6$ Btu using procedures specified in Subpart D for each sampling period.

(4) Average the two sampling period results obtained during each run.

(5) Arrange the three sample run results in units of $lbs/10^6$ Btu to determine the test result.

For NO_x emission level determinations at NSPS Subpart D sources, the same procedures apply as for SO_2 determinations, except that each sampling run may be treated as a single value (i.e, the sampling run need not be divided into two sampling periods). Note that the results of three sample runs expressed in units of $lbs/10^6$ Btu are averaged to obtain the test result.

C. SO_2 and NO_x CEM Relative Accuracy Tests

(1) Ignore the first 5 minutes of data obtained during each sampling run to allow for complete system stabilization following the system calibration.

(2) Determine the integrated average effluent levels for all monitoring channels in use for each sampling run. Convert the effluent levels to equivalent effluent concentrations for each monitoring channel using the procedure in "A" above. Also, calculate the average pollutant and diluent concentrations using the results of all sampling runs.

(3) Using the pollutant and diluent measurement results, calculate the emission levels in units of $lbs/10^6$ Btu for each sampling run. Calculate the average of all TCEMS sampling runs in units of $lbs/10^6$ Btu.

(4) Determine the installed CEMS monitoring results (pollutant concentration, diluent concentration, and emission levels) for the periods concurrent with each sampling run of the TCEMS using the same procedure that is employed by the source operator in reporting emissions.

(5) The mean difference, 95 percent confidence interval, and relative accuracy must be computed for each monitoring channel and for the combined system in units of $lbs/10^6$ Btu.

Calculate the algebraic mean difference of the data set as follows:

$$MD = 1/n \sum_{i}^{n} D_i$$

where: n = number of data points

D_i = sample run (i) difference
$(CEMS_i - TCEMS_i)$

Calculate the 95 percent (two-sided) confidence interval (CI) as follows:

$$CI = \frac{t_{.975}}{n\sqrt{n-1}} \sqrt{n\Sigma D_i^2 - (\Sigma D_i)^2}$$

where:

n	$t_{.975}$
3	4.303
4	3.182
5	2.776
6	2.571
7	2.447
8	2.365
9	2.306

Calculate the relative accuracy (RA) of the data set as:

$$RA = \frac{|MD| + CI}{AVG}$$

where: AVG = average TCEMS value for all sample runs.

APPENDIX I.

PRINCIPLES OF OPERATION:

SO_2, NO/NO_x, CO_2, AND O_2 ANALYZERS

PRINCIPLES OF OPERATION;

SO_2, NO/NO_x, CO_2, AND O_2 ANALYZERS

The following discussions briefly outline the operational principles of each analyzer used in the TCEMS. Additional information may be found in the instrument manuals provided by the manufacturers.

A. Beckman Model 865 SO_2 Analyzer

The Model 865 Infrared SO_2 Analyzer automatically and continuously determines the concentration of SO_2 in a flowing gas mixture. The analytical technique is based on the absorption of infrared energy by SO_2.

Within the analyzer, two infrared beams of equal energy are directed through two optical cells: a flow-through sample cell, and a sealed reference cell. Solid state electronic circuitry continuously measures the difference between the amounts of infrared energy absorbed in the two cells. The concentration is read out on a front panel meter which has a range from 0 to 100 percent. A field-selectable current output of either 4 to 20 ma or 10 to 50 ma is provided for strip chart recorder connection.

Since the outputs of these instruments are non-linear, an optional linearizer circuit board is also included. A solenoid activated reflecting window is provided for routine upscale calibration. This window reflects a fixed amount of infrared energy from the sample beam to simulate a specified concentration of SO_2. The instrument is equipped with two ranges: Range 1, which is adjustable (from 500 to 2500 ppm full scale), and Range 3, which is equal to 20 percent of Range 1. (Range 2 is omitted from this instrument.)

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B. Beckman Model 951 NO-NO_x Analyzer

The Beckman Model 951, NO-NO_x Chemiluminescence Analyzer automatically and continuously monitors a flowing gas mixture. It is capable of performing two determinations: nitric oxide (NO) and oxides of nitrogen (NO_x).

The analyzer employs the chemiluminescence method of detection. When the analyzer is adjusted to the NO mode, the sample NO is quantitatively converted to NO_2 by gas phase oxidation with ozone produced within the analyzer. In this reaction, the NO_2 molecules are elevated to an electronically excited state and then immediately revert to a non-excited ground state. The reversion is accompanied by emission of photons, which impinge on a photomultiplier detector and generate a low level DC current. The current is then amplified and used to drive a front panel meter and a recorder.

The NO_x mode works by the same principles as the NO mode described above, with the exception that the sample is routed through a converter where NO_2 is dissociated to form NO before entering the reaction chamber. The NO_x reading on the instrument includes both the NO in the effluent and the NO resulting from the dissociation of NO_2.

The analyzer is equipped with seven ranges: 10, 25, 100, 250, 1000, 2500, and 10,000 ppm NO or NO_x.

C. Beckman Model 864 CO_2 Analyzer

The Beckman Model 864 Infrared CO_2 Analyzer automatically and continuously determines the concentration of CO_2 in a flowing gas mixture. The analysis is based on the absorption of infared energy of CO_2.

Within the analyzer, two infrared beams of equal energy are directed through two optical cells: a flow through sample cell, and a sealed reference cell. Solid sate electronic circuitry continuously measures the difference between the amounts of infrared energy absorbed in the two cells. The concentration is read out on a front panel meter with a scale of 0-100 percent of set range. A field selectable current output, 4 to 20 ma or 10 to 50 ma, is provided for a recorder hook-up.

Since the output of the instrument is non-linear, a linearizer circuit board has been provided. For convenience in a routine upscale calibration, a solenoid activated reflecting window has been included. This window reflects a fixed amount of infrared energy from the sample beam to simulate a specific concentration of CO_2. The instrument is equipped with two ranges: Range 1, equal to 0 to 20% CO_2, and Range 3, equal to 0 to 5% CO_2. (Range 2 is omitted from this instrument.)

D. Teledyne Model 320P-4 O_2 Analyzer

The Teledyne Model 320P-4 utilizes a patented micro-fuel cell, which consumes O_2 from the atmosphere surrounding the measuring probe. The consumption of O_2 generates a proportional electrical current, which is then amplified and used to drive a built-in front panel meter with a scale of 0 to 25%. Facilities are also provided for a recorder hook-up with a range of 0 to 100 mv DC.

The instrument incorporates its own integral pump and power system. The power system consists of two permanently mounted rechargeable nickel-cadmium batteries.

The 320P-4 monitor has been specifically designed to make spot checks for O_2 in flue gas streams.

APPENDIX II.

STRATIFICATION TESTING METHODOLOGY FOR GASEOUS EFFLUENT CONSTITUENTS

STRATIFICATION TESTING METHODOLOGY FOR GASEOUS EFFLUENT CONSTITUENTS

Stratification is the uneven distribution of the effluent component gases across the cross section of the ductwork or stack which transports the effluent to the atmosphere. Stratification of gaseous constituents (SO_2, NO_x, O_2, CO_2, etc.) may occur at or downstream of points along the effluent pathway where the concentration of one of more constituents of the effluent changes. Thus, points at which air inleakage occurs, points at which control devices affect pollutant emission levels (such as at the outlet of flue gas desulfurization systems), and points at which dissimilar gas streams are combined may result in stratification of the effluent stream. Samples obtained at locations where stratification exists may not provide results that are representative of the entire effluent stream. It is necessary, in some cases, to conduct a test to detect and/or to quantify the existence of stratification at the existing or proposed sampling site. The procedures presented in this report are designed to determine whether effluent stratification is present; this methodology does not quantify the stratified effluent profile.

Current Performance Specifications for gaseous emission monitors require that monitors be installed in locations providing measurements that are (or can be corrected to be) consistently representative of emissions from the source. These regulations allow the control agency to require stratification testing at proposed CEM sampling locations where the location cannot be assumed to be non-stratified.

Proposed revisions to the Performance Specifications (Jan. 26, 1981, Federal Register) allow the monitor to be installed at any location provided

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that the reference method testing to determine the relative accuracy of said monitors be performed in locations that are representative of the source's emissions. Stratification testing is an accepted means of demonstrating that particular sampling locations provide representative emission measurement results.

Stratification can be measured for either pollutant gases (SO_2 or NO_x) or diluent gases (O_2 or CO_2) in units of concentration. Alternatively, at steam generators, stratification may be quantified in units of the applicable standard (lbs of pollutant per million Btu of heat input). This second alternative is useful where both the pollutant and diluent monitors are installed in such a manner as to view the same portion of the effluent and where the potential for stratification is due only to air inleakage. Also, testing to determine the representativeness of a compliance test sampling location should be conducted in units of the standard.

The only quantitative definition for stratification that is provided in the existing regulations is contained within Paragraph 3.9, Performance Specification 2, Appendix B, 40 CFR 60. The definition is as follows:

> "3.9 Stratification. A condition identified by a difference in excess of 10 percent between the average concentration in the duct or stack and the concentration at any point more than 1.0 meters from the duct or stack wall."

Paragraph 4.3 of this specification provides the only guidance regarding the sampling methodology to be used to determine whether stratification exists; this paragraph reads:

> "4.3. The owner or operator may perform a traverse to characterize any stratification of effluent gases ... ."

Thus, stratification testing is performed by making a series of traverse measurements across the stack or duct sampling location. To determine whether or not effluent stratification exists as per the above definition, the average effluent concentration across the stack or duct must also be known during each measurement made along the stack traverse. Determining the average effluent concentration concurrent with each traverse point meaurement presents some difficulties. Ideally, concurrent determinations could be made by simultaneously measuring emissions at several points along the cross section of the duct or stack. However, this approach is not feasible because of the extensive manpower and equipment required to measure spatial stratification. To ensure that the stratification determination is not affected by temporal changes in the average effluent concentration, a sampling and calculation method was developed to eliminate the effects of such temporal variations. This method employs a dual probe system to sample alternately at a traverse point and a reference point.

Steady operation is preferable for stratification testing, because the results are unaffected by incremental effluent concentration shifts caused by changing process conditions. If stratification testing is performed on sources operating under batch process conditions, the testing should be conducted during segments of steady operation.

EQUIPMENT DESCRIPTION

The sampling apparatus necessary for stratification testing is an extractive continuous monitoring system comprised of the following: a sample acquisition and gas conditioning system; SO_2, CO_2, O_2, and/or NO_x monitors; strip chart recorders; and an automatic data processor (optional). The sample

acquisition system consists of two heated stainless steel sampling probes, and the monitoring system is capable of alternately measuring the effluent extracted through each of the two probes. A detailed description of the extractive monitoring system, along with its calibration and sampling procedures, is contained in a document prepared for the EPA, SSCD, entitled, "Transportable Continuous Emission Monitoring System Operational Protocol".

SAMPLING PROCEDURE

To eliminate the effects of temporal variations of the average effluent concentration, all effluent measurements must be normalizd to a specific point in time ('t') before the average concentration and percent difference at each traverse point are calculated; therefore, a dual probe system is used to measure the effluent emissions. One probe is used as a stationary reference point placed at the stack or duct centroid during the stratification sampling period; this probe is used to indicate the temporal change of the effluent concentrations. The second probe is used for sampling at specified traverse points determined in accordance with the sampling point location criteria of Paragraph 3.3.1 of proposed revisions to Performance Specification 2, Appendix A, 40 CFR 60 (Federal Register, Vol. 44, No. 197, October 10, 1979). The monitoring system samples at the reference point, traverse point, reference point, etc., sequentially throughout the testing period for three (3) to five (5) minutes at each point. The monitoirng system is calibrated with gases analyzed by the reference methods immediately before and after the stratification test.

CALCULATION PROCEDURE

The derivation of the stratification calculation procedure is based on two principle assumptions:

1. For each traverse point x, there exists a unique constant of proportionality between the concentrations of the Reference point and traverse point, such that:

$$T_x = K_x R_x \qquad \text{[EQ. 1]}$$

where: T_x = Concentration at traverse point x
K_x = Proportionality constant for point x
R_x = Reference point concentration
x = 1, 2, 3. . .

This relationship implies that:

$$K_x = \frac{T_x}{R_x} \qquad \text{[EQ. 2]}$$

2. All changes in effluent concentration occur in such a manner that the average concentration for a given measurement time interval is approximately equal to the average of the concentrations measured before and after that measurement time interval.

Thus, the average Reference concentration at a time when the traverse point concentration is being measured is equal to the average of the reference concentrations measured before and after the traverse point concentration measurement.

$$R_x = R_{xab} = \frac{R_{xb} + R_{xa}}{2} \qquad \text{[EQ. 3]}$$

where: R_{xb} = Reference concentration before measurement of traverse point x

R_{xa} = Reference concentration after measurement of traverse point x

In order to compare one traverse point measurement to another on a consistent basis, the effect of effluent concentration changes with time must be eliminated. Consequently, all traverse point measurements must be normalized to some benchmark reference time, t.

$$T_{xn} = K_x \, R_t \qquad \text{[EQ. 4]}$$

T_{xn} = normalized value of concentration for point x

K_x = proportionality constant, defined in EQ. 2

R_x = Reference concentration at reference time, t

Equation 4 results in the value that would have been measured for traverse point x if the reference concentration had been equal to R_t.

Combining EQ. 2 and EQ. 4 and simplifying the resultant normalized concentration is:

$$T_{xn} = \frac{T_x}{R_x} \, R_t$$

Changes in effluent flow rate or other process operating parameters, such as failure of a fan, could cause changes in the nature of any stratification present. This could cause the K_x values to change, rendering normalized traverse concentrations inaccurate. Again, this is only a problem if stratification does exist, and the test will still detect this stratification, although it will not accurately quantify it.

The second assumption may provide a more likely reason for inaccurate indications of the magnitude of effluent stratification. This assumption is valid only if the sampling time for each traverse point is small compared to any cyclic changes in the effluent concentrations, or if the magnitude of these changes in concentration is small. As changes in concentration become larger, the assumption that:

$$R_x = \frac{R_{xb} + R_{xa}}{2}$$

becomes more critical. Errors in this assumption become more pronounced as the measurement time period approaches one-half the time period of a cyclic concentration change. The most likely result of such errors is an overestimation of stratification. Thus, the perviously discussed stratification test procedure will err conservatively, and indications of no stratification can be viewed with a high level of confidence.

Source and Location _____

Sample Point	Reference Probe			Traverse Probe			Ave. Ref. Probe			Temporal Change			Normalized Trav.		
	SO_2 (ppm)	NO_x (ppm)	CO_2/O_2 (%)	SO_2 (ppm)	NO_x (ppm)	CO_2/O_2 (%)	SO_2 (ppm)	NO_x (ppm)	CO_2/O_2 (%)	SO_2 (%)	NO_x (%)	CO_2/O_2 (%)	SO_2 (ppm)	NO_x (ppm)	CO_2/O_2 (%)

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16. ABSTRACT

A transportable continuous emission monitoring system (TCEMS) capable of providing reliable and accurate effluent measurements of SO_2, NO/NO_x, CO_2, and/or O_2 has been developed and field tested at numerous industrial and utility boilers. This report presents the operational protocol for the TCEMS, including set-up, operation, calibration, quality assurance, and data reduction procedures. The TCEMS and the operational protocol are designed for use in conducting source emission tests, continuous emission monitor (CEM) relative accuracy tests, and stratification tests. Extensive field testing has shown that the TCEMS can be set up, calibrated, and recording accurate and precise data within two to four hours after arrival at the site.

17. KEY WORDS AND DOCUMENT ANALYSIS

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